

# Measuring the influence of Cooperative Learning and Project Based Learning on problem solving skill

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**Abstract:** *The aim of this study is to evaluate the effects obtained after applying two active learning methodologies (cooperative learning and project based learning) to the achievement of the competence problem solving. This study was carried out at the Technical University of Madrid, where these methodologies were applied to two Operating Systems courses. The first hypothesis tested was whether the implementation of active learning methodologies favours the achievement of “problem solving”. The second hypothesis was focused on testing if students with higher rates in problem solving competence obtain better results in their academic performance. The results indicated that active learning methodologies do not produce any significant change in the generic competence “problem solving” during the period analysed. Concerning this, we consider that students should work with these methodologies for a longer period, besides having a specific training. Nevertheless, a close correlation between problem solving self appraisal and academic performance has been detected.*

## Introduction

The Bologna Process (2009a) establishes the priorities for the European Higher Education Area (EHEA) until 2020. On the one hand, the significance of student-centred learning and the teaching function for the EHEA are emphasized. “Student-centred learning requires empowering individual learners, new approaches to teaching and learning, an effective support and guidance structures, and a curriculum which is more clearly focused on learners along the three cycles” (Bologna Process, 2009b). Active learning methodologies such as Cooperative Learning (CL) and Project Based Learning (PBL) can be found among the approaches adopted in teaching and learning. Besides, both of them have been recognized as appropriate methodologies in several documents related to the university context of engineering in Spain, such as “Libro Blanco del Título de Grado en Ingeniería Informática” (ANECA, 2004) and “Modelo Educativo UPM” (UPM, 2010).

On the other hand, one of the objectives of the EHEA is helping students to develop generic competences which they will use during their professional practice. Some of them are specific to one degree, but others are considered generic competences and can be achieved in most of the profiles: “planning and time management”, “teamwork” or “problem solving” among them. Whilst specific competences can be developed by carrying out different teaching/learning tasks, some of the generic competences need specific training programmes to cover skill gaps during the degree.

The Educative Innovation Group DMAE-DIA (<http://c3po.eui.upm.es/dmae/dmaeing.html>) of the Technical University of Madrid (Universidad Politécnica de Madrid, UPM) has been using these methodologies for several years (García, Manzano, Pérez-Martínez and Muñoz, 2007; García, Pérez, Muñoz and Manzano, 2008; García, 2009; García and Pérez-Martínez, 2009; Pérez-Martínez, García and Muñoz, 2008; Pérez-Martínez, García, Muñoz, Sierra-Alonso and López, 2010). This group is aimed at: 1) achieving a more active participation of students in the learning/teaching process; 2) improving students’ academic performance by promoting specific competences and 3) promoting the development of generic competences. In the University School of Computer Science (Escuela Universitaria de Informática, EUI), this group is conducting some experiments in order to verify the

influence of using different teaching methodologies both from the point of view of academic performance and the acquisition of generic competences. Some of these previous works (García, Manzano, Pérez-Martínez, Rodríguez and Alcover, 2010; Pérez-Martínez, García, Muñoz and Sierra-Alonso, 2010) do not show significant improvements in “Planning and time management” or “Teamwork” with the methodologies adopted during the academic years 2006/2007, 2007/2008 and 2008/2009.

In this work, we present the experience of applying CL, based on a jigsaw technique (Johnson, Johnson and Stanne, 2000; Felder and Brent, 2001), and PBL to an Operating System course. With PBL methodology, students face more open problems which need to be studied in a more autonomous way. The work developed by students with CL is more directed and they have to deal with well-defined problems. The study is aimed at evaluating the effect of these active learning methodologies on the development of problem solving generic competence.

Nowadays each university in the EHEA is defining the level of competences which their graduates must achieve. Every university needs to know the degree in which their graduates have reached that level. Traditional exams and written tests are focused on measuring the level acquired in specific competences, those related to subject contents. But there is less experience in measuring generic competences such as “problem solving”. Therefore, we consider it necessary to specify a mechanism to evaluate the influence that active learning methodologies have on the achievement of generic competences. The importance of this study is based on the use of verified and scientifically validated instruments to evaluate the effect of CL and PBL on the development of the skill “problem solving”. As far as we are concerned, no studies of this nature have been published before.

The following hypotheses were contrasted. Hypothesis 1: “The improvement achieved by students in the problem solving generic competence would be higher if PBL is applied to the subject (ill-structured problems and autonomous work) than in those cases in which CL is applied (more directed work)”. Hypothesis 2: “Students with higher rates in problem solving competence obtain better results in their academic performance”.

This paper is structured as follows: Section 2 describes the experiment that developed. This way, we will describe the participants who have taken part in the study, the teaching practice used, as well as the way in which data analysis have been carried out. Section 3 presents the study results. Then, discussion section will provide the conclusions of this work, some future proposals and the main limitations of this project.

## **Method**

### **Participants**

This study has been carried out at the UPM, where CL and PBL have been applied to two groups of Operating Systems subject: Operating System I (OS-PBL), taught in the fourth semester of Technical Engineering in Computer Science degree (second term of 2010), and Operating System (OS-CL), taught in the fifth semester of Computer Engineering (first term of 2011). Both subjects have the same syllabus, are taught in similar semesters, share formative objectives and use common teaching material. The latter syllabus, OS-CL, has been taught applying CL to a group of 19 students, who worked in groups of four students. The former, OS-PBL, has been taught applying PBL to 40 students, who were divided in teams of four components as well.

### **Procedure**

Both subjects, OS-CL and OS-PBL, need to cover five topics: Introduction, Process and Threads, Memory Management, Input/Output and File Systems and have been taught for 15 weeks, with four hour per week, one two-hour theoretical session and another two-hour laboratory session.

In the subject OS-PBL, the tasks which constitute the project will be carried out by groups of 4 or 5 students, on the one hand. This project is aimed at making a comparison between the operating systems Windows XP and Linux along the course, regarding the aspects included in the syllabus of the subject. At the end of the term, students should be able to explain a series of essential differences and

similarities between both operating systems, from the point of view of their interface, implementation and performance. The project will be divided into 4 tasks. Students will tackle a different topic in each of the works, which will be related to the contents of the syllabus. The professor will suggest a series of topics; however, any group can work on another topic suggested by them, which has to be previously agreed with the professor. The development of each topic consists of three phases. First, students carry out a search and study of information. Then, they have to design an experiment approaching the comparison between Linux and Windows XP, with regard to the topic studied. Finally, they present a report with all the work carried out, including the results obtained in the experiment, and also make an oral presentation. At the end of the term, a debate is established focusing on all the projects developed by students in order to answer a series of open questions: Are Linux and Windows XP actually so different? Is there any significant difference regarding their performance? Does any of the operating systems offer more advantages from the point of view of programming?

On the other hand, CL was applied to the fifteen OS-CL sessions. At the beginning of the course, permanent groups of four students (base groups) were formed. Because of CL, each member of a group had to be an expert on some basic concepts of the topic during each session. For this reason, the kind of homework which students were given depended on the type of expert. There were four kinds of homework, one addressed to each expert. For each session, this homework was structured into three parts: the first described the learning objectives and skills to be acquired with the homework; the second indicated the information to be studied, and the third part consisted in solving basic problems, developing a simple programme or answering some questions. Both the second and the third part were set estimated periods of time to be carried out. Homework had to be handed to the professor before the session concerned started and the real amount of time it took them to do it had to be indicated. Along each session, CL method was put into practice and all base groups tried to solve a problem which required the knowledge of the four experts (jigsaw). At the end of the session there was a global discussion about the difficulties encountered and the different ways to solve the problems.

Several individual written assessments were made along the term. More specifically, three test, three short-answer questionnaires and two problems. These assessments were very similar in both courses. The individual mark obtained in these tests meant 50% of the final mark.

## **Measuring and Instruments**

The instrument used to measure the problem solving competence is the Problem Solving Inventory test (PSI) (Heppner, 1988) whose purpose is to assess a students' perception of his or her own problem-solving behaviours and attitudes. It has 35 items and is divided into three scales: Problem-Solving Confidence (CON), Approach-Avoidance Style (AA) and Personal Control (PC). The results obtained according to three scales can be analysed individually, although a total PSI score can be used as a single index of problem-solving appraisal.

In each item (statement), participants have to evaluate their own perception following a 6-point Likert-type scale (1= Strongly Agree; 6 = Strongly Disagree). Therefore, low scores on all scales and for the Total PSI score represent positives appraisals of problem-solving abilities. This test was filled out by students of both courses at the beginning and also at the end of each term.

## **Data analysis**

For the Statistical Analysis we used version 5.1 of the statistical program STATGRAPHICS (SPSS Inc., 2006). In order to test the first hypothesis, the effect of CL and PBL on problem solving competence, we compared the mean obtained in the PSI test measured both before and after active learning methods. This work was made individually in OS-CL and OS-PBL. The Kolmogorov-Smirnov test was used to determine if data can be adequately modelled by a normal distribution. We run a t-test with a significance level of 0.05 to decide whether the equality of the means could be considered.

The second hypothesis was tested by analysing the correlation between PSI scores and the marks obtained by students in the individual assessments. The Pearson Correlation Coefficient was used with

a significance level of 0.05. More specifically, we analysed the correlation between PSI marks and four written individual marks: MT (mean mark obtained in tests), MQ (mean mark obtained in short-answer questionnaires), MP (mean mark obtained in problems) and MI (individual global mean mark).

## Results

Table 1 shows the means and standard deviation obtained for each subscale and the total PSI test. All these variables fit a normal distribution, according to Kolmogorov-Smirnov test. In order to test hypothesis 1, a t-Student test for related measurements (with a significance level of 0.05) was used to compare the means obtained in each variable at the beginning and at the end of the course as well.

A statistically significant difference was not found when comparing PSI means, neither in the OS-CL group nor in the OS-PBL group. In the OS-CL case, we obtained  $t [15] = 1.226$ ,  $p=0.243$ , whilst in OS-PBL group the results were  $t [33] = -0.156$ ,  $p=0.877$ . As far as subscales is concerned, the only case in which we obtained significant differences was the AA scale in OS-CL ( $t [15] = 2.539$ ,  $p=0.023$ ). The other subscales of the OS-CL group as well as every subscale of OS-PBL showed high p values.

**Table 1. Mean and Standard Deviation (SD) in generic competences**

Generic Competence	OS-CL		OS-PBL	
	beginning	end	beginning	end
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Approach-Avoidance Style (AA)	48.63 (8.831)	45.19 (8.248)	45.81 (10.381)	45.57 (10.433)
Problem-Solving Confidence (CON)	27.19 (7.432)	28.56 (6.572)	25.24 (8.197)	26.67 (10.012)
Personal Control (PC)	15.94 (3.021)	15.81 (3.311)	14.43 (4.411)	15.19 (4.106)
Total PSI score (PSI)	91.63 (16.633)	89.56 (15.077)	85.38 (20.250)	87.43 (23.329)

Regarding hypothesis 2, Table 2 shows the Pearson Coefficient and the significance level for each variable correlation. Significant correlations are marked with asterisks: (\*) if the significance level is 0.05 and (\*\*) if the significance level is 0.01. As it has been explained before, low scores on all scales and for the Total PSI score represent positives appraisals of problem-solving abilities. Therefore, we should highlight negative correlations, which point out that the more positive appraisal the student has about his problem solving ability, the better mark he obtains in the individual assessment.

**Table 2. Pearson Correlation Coefficient between PSI and individual marks**

	OS-CL				OS-PBL			
	MI	MT	MQ	MP	MI	MT	MQ	MP
Approach-Avoidance Style (AA)	-,410 ,057	-,509(*) ,022	-,390 ,068	,082 ,382	,184 ,149	,178 ,157	-,007 ,485	,166 ,174
Problem-Solving Confidence (CON)	-,479(*) ,030	-,399 ,063	-,410 ,057	-,223 ,204	-,347(*) ,022	,027 ,440	-,385(*) ,012	-,440(**) ,005
Personal Control (PC)	-,601(**) ,007	-,349 ,092	-,729(**) ,001	-,217 ,210	,112 ,265	,402 ,009	-,157 ,188	-,083 ,321
Total PSI score (PSI)	-,553(*) ,013	-,524(*) ,019	-,536(*) ,016	-,094 ,365	,014 ,468	,229 ,096	-,192 ,138	-,083 ,321

Although the strongest correlations have been obtained between PC variable and OS-CL individual marks, the only scale that shows correlation with individual marks on both courses is Problem-Solving Confidence (CON). It particularly has a correlation with the overall mean mark (MI) with a significance level 0.05. If we compare both courses, we observe that a stronger correlation is found in OS-CL.

## Discussion

Regarding the first hypothesis, we can conclude that the application of CL and PBL methodologies did not suppose a significant improvement to students in the “problem solving” competence when it is measured at the beginning and at the end of the term. These measures contradict the conclusions described in some previous studies (Dochy, Segers, Van den Bossche and Gijbels 2003).

Several studies have checked the validity of the PSI test (Heppner 1988; Sahin 1993) and we have found two reasons that could explain the results obtained in this work. Firstly, a semester may be a very short period of time to obtain significant improvement in the measures carried out at the beginning and at the end of the term in which the methodologies have been used. Secondly, it is possible that the methodologies alone do not improve the generic competence that we studied. We conclude that students need some specific and extensive training on “problem solving” before applying it to learning methodology. In the next years, we will include some seminars to guide students in the development of generic competences. Besides, we will programme the competence measures in order to assess students’ progress along several years. Finally, we highlight the advisability of having a control group with traditional lectures so that we could study the significant differences with active learning methodologies.

As far as the second hypothesis is concerned, we observe certain correlations between problem solving self-appraisal and individual marks. In particular, the scale Problem-Solving Confidence (CON) seems to be the most constant since the correlations happened in both courses. Besides, the lowest correlation obtained with the Approach-Avoidance (AA) variable could be explained by the kind of problem solved individually by students in the written tests. These problems are well-defined and short, so they do not require an important strategy to be solved.

In future years we find greatly important the integration of a general competences training in current curricula. The proposal will consist in developing a map which distributes general competences among semesters in a balanced way. The subjects which constitute a semester will imply some practical credits so that the general competences selected for this semester could be taught. Then, subjects will foster the use of these skills and they will require that students show enough ability related to these skills according to the training they have received. The first terms will deal with basic competences, ‘teamwork’, ‘problem solving’, ‘written expression’ or ‘time management’ among them. Further terms will tackle more advanced competences.

## Limitation of the Work

The limited number of participants may have influenced the results. In further years, a higher number of students will follow this subject. This way, a deeper analysis will be possible.

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